MODEL TDA-121
NANOVOLTMETER

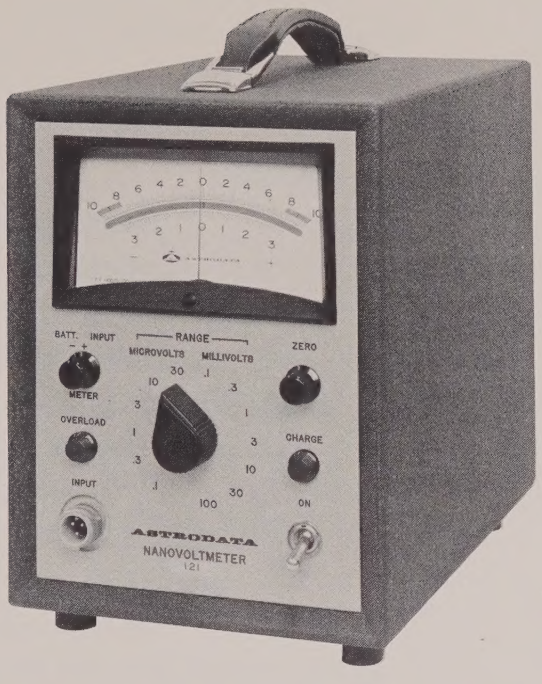
ASTRODATA

240 E. Palais Rd., Anaheim, California

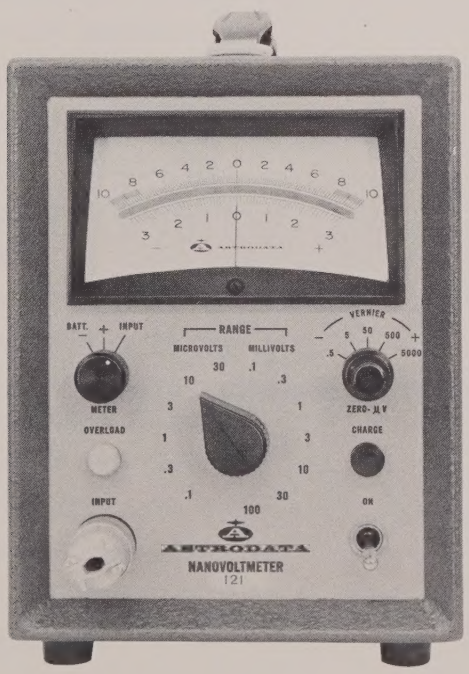
INSTRUCTION MANUAL

FRANK HARRIS

MODEL TDA-121
NANOVOLTMETER



MODEL 121



MODEL 121
WITH MODIFICATION Z

ASTRODATA MODEL 121 NANOVOLTMETER

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TABLE OF CONTENTS

Para.	Title	Page
1.0	INTRODUCTION	1
2.0	SPECIFICATIONS	2
3.0	OPERATING INSTRUCTIONS	8
3.1	EXTERNAL CONNECTIONS	8
3.1.1	Rear Panel Connections	8
3.1.2	Front Panel Connector	9
3.1.3	AC Power	9
3.2	BATTERY OPERATION	10
3.2.1	Battery Charging	10
3.2.2	Meter Switch	11
3.3	PREPARING THE INPUT LEADS	11
3.3.1	Principles of Thermocouple Construction	11
3.3.2	ASTRODATA Soldering Kit	13
3.3.3	Soldering Procedure	14
3.4	GAIN SELECTION	15
3.5	ZERO SUPPRESSION	16
3.6	OVERLOAD INDICATOR	16
4.0	THEORY OF OPERATION	16
4.1	GENERAL	16
4.2	SCHEMATIC ANALYSIS	18
4.2.1	Low Level Modulator	18
4.2.2	Charging Circuit, Chopper Drive Circuit and Overload Circuit	20
4.2.2.1	Chopper Drive Circuit	20
4.2.2.2	Overload Circuit	21
4.2.2.3	Charging Circuit	21
4.2.3	D.C. Amplifier	22
4.2.3.1	Amplifier No. 1	23

TABLE OF CONTENTS (Cont'd)

Para.	Title	Page
4.2.3.2	Amplifier No. 2	23
4.2.3.3	Overload Indication	24
4.2.3.4	±3.25 V DC and -3.25 V DC Power Supplies	24
4.2.4	Front Panel Model 121	25
4.2.4.1	Zero Suppression Circuit	25
4.2.4.2	Summing Junction	25
4.2.4.3	Battery Test and Meter Circuit	26
4.2.5	Range Switch Model 121	26
4.2.5.1	RANGE Switch	27
4.2.5.2	Auto Gains No. 1 and No. 2	27
5.0	PREVENTIVE MAINTENANCE	27
5.1	BASIC TROUBLESHOOTING PROCEDURE	28
5.1.1	Possible Operator Error	28
5.1.2	Problem Isolation	28
5.1.3	Check Power Circuits	29
5.1.4	Checking Circuit Cards	29
5.1.5	Troubleshooting - DC Amplifier	29
5.2	COMPONENT AND ELEMENT MAINTENANCE	30
6.0	DRAWINGS	31

LIST OF ILLUSTRATIONS

Frontispiece - ASTRODATA Model 121 Nanovoltmeter

Number	Title	Page
Figure 1	Simplified Block Diagram Model 121 Nanovoltmeter	1a

DRAWINGS AND SCHEMATICS

Number	Title
121-8001	Block Diagram Model 121Z, Serial No. 187 Up
121-1010	Front Panel Model 121Z
121-1017	Range Switch Model 121 & 121Z
121-1019	Low Level Modulator
11863	Charging Circuit, Chopper Drive Circuit & Overload Circuit TDA-121 & 121Z Serial No. 112-
11856	D.C. Amplifier Model TDA-121 & 121Z

INSTRUCTION MANUAL
for
MODEL 121
NANOVOLTMETER

1.0 INTRODUCTION

The Astrodata Model 121 Nanovoltmeter is a transistorized potentiometric amplifier used to measure low-level DC voltages. A front-panel switch selects meter sensitivity of from 0.1 microvolt to 100 millivolts full-scale.

The Astrodata Nanovoltmeter is designed to withstand inputs of up to 1.0 volt AC or DC at any selected range, without instrument damage. The Nanovoltmeter is connected as an integrator with a nominal 0.4 second time constant so that AC signals superimposed on the DC voltage to be measured are attenuated. When these AC signals are large enough to overdrive the Nanovoltmeter, an OVERLOAD lamp lights, indicating that the reading may be in error.

NOTE

References to the Astrodata Model 121 Nanovoltmeter in this manual, include the 121Z modification.

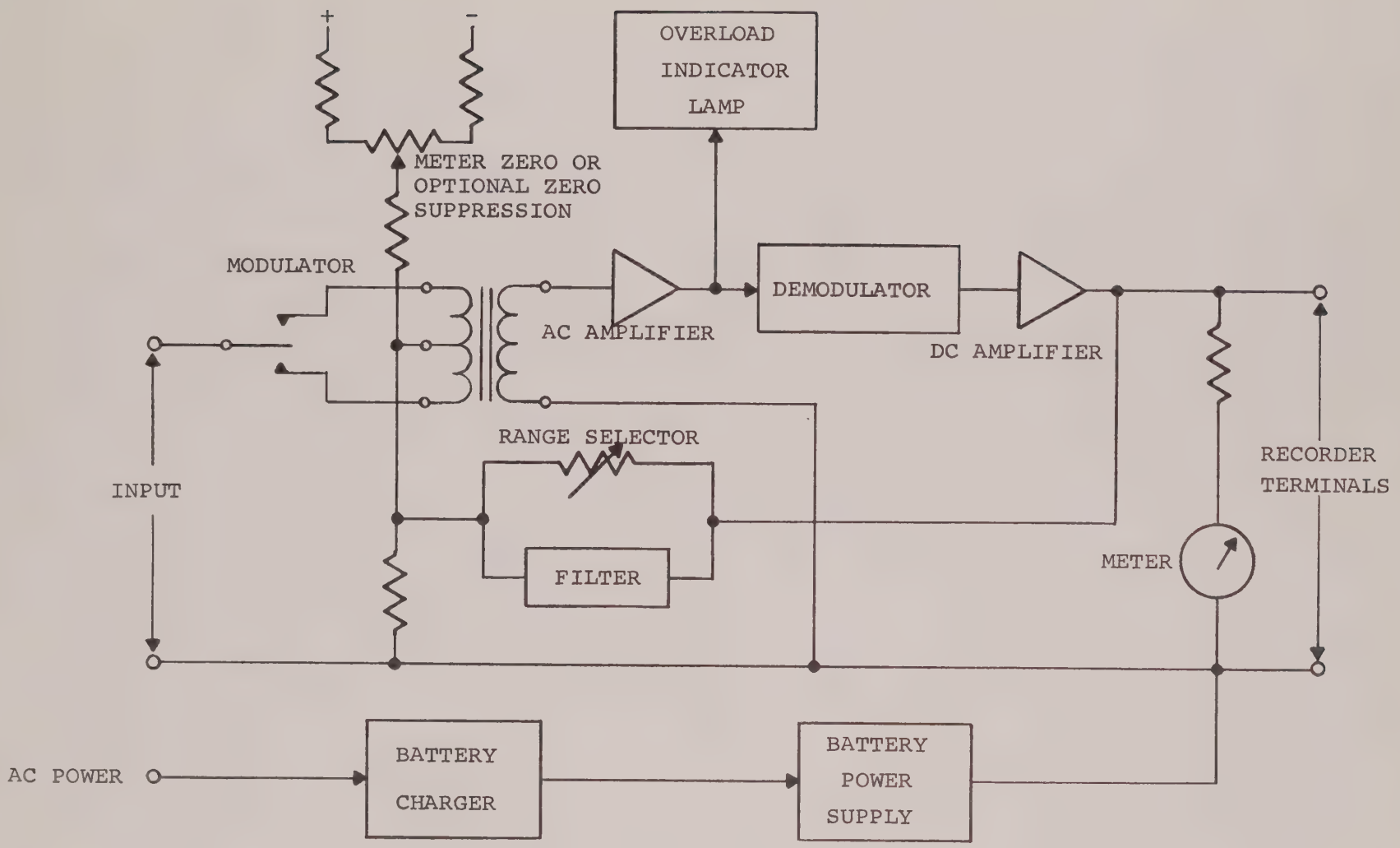


FIGURE 1: SIMPLIFIED BLOCK DIAGRAM MODEL 121 NANOVOLTMETER

2.0 SPECIFICATIONS

Voltage Ranges:	Full-scale center-zero ranges of ±0.1 microvolt to ±100 millivolts DC in X1, X3, X10, etc., steps.
Input Overload Range:	Withstands up to 1 volt input on all ranges.
Input Resistance:	At least 1 megohm on all ranges.
Accuracy:	±3% of full-scale on all ranges.
Zeroing Range:	Nominally ±3 microvolts. See Modification Z for optional zero suppression feature.
Zero Drift:	Less than: 0.05 μv/hour; 0.15 μv/day; 1 μv/6 months (non-cumulative) with shorted input. On 100 μv range and higher, drift is less than 0.03% of full-scale per day.

Noise:	Less than 0.005 μv rms when source resistance is 100 ohms or less; less than 0.01 μv rms when source resistance is 2000 ohms or less. With higher source resistances the rms noise is less than $0.01\left[\frac{R}{2000}\right]$ μv, where R is the source resistance in ohms. On the 100 μv range and higher, noise and hum is less than 0.02% of full-scale.
Step Function Response:	Meter response to step function input (10% to 90% of full-scale) is less than 1 second for a source resistance of less than 0.5 megohms.
60-cps Filtering:	Built-in filtering allows the following amounts of 60-cps signal to be superimposed on the dc signal to be measured without impairing accuracy. The filtering factor at frequencies other than 60-cps is inversely proportional to the frequency.

NANOVOLTMETER FULL-SCALE RANGE	NOMINAL SUPERIMPOSED 60-CPS VOLTAGE PEAK-TO-PEAK	FILTERING FACTOR* AT 60 CPS
0.1 μv	100 μv	1000
0.3 μv	200 μv	667
1 μv	300 μv	300
3 μv	900 μv	300
10 μv	1 mv	100
30 μv	1 mv	33
100 μv	3.3 mv	33
300 μv	10 mv	33
1 mv	33 mv	33
3 mv	100 mv	33
10 mv	100 mv	10
30 mv	100 mv	3.3
100 mv	100 mv	1

*The filtering factor is the ratio of the peak-to-peak AC voltage which will not impair accuracy, divided by the full-scale range.

Amplifier Gain Range:	Amplifier gain may be selected from 30 to 3 million in steps of X1, X3, X10, etc.
Amplifier Gain Accuracy:	±1%.
Amplifier Gain Stability:	±0.02% for 1000 hours.
Amplifier Bandwidth:	Down 3db at 0.2 cps.
Recorder Output:	The Nanovoltmeter supplies up to ±5 volts at ±5 milliamperes at two five-way binding posts on the rear panel. The Nanovoltmeter output connections and front-panel meter may be used simultaneously.
Ground Isolation:	The entire circuit is floating from panel and cabinet by at least 1000 megohms resistance and not more than 0.01 mf capacitance. The input may be floated up to ±300 volts DC with respect to panel or cabinet. Circuit ground may be connected to cabinet ground at binding post adjacent to output terminals, with link provided.

Power Requirements:	115 volts rms ±10%, 50 to 70 cps, approximately 2 watts; or internal batteries. Unit may be operated for approximately 20 hours without recharging.
METER SPECIFICATIONS:	100/0/100 micro-amp pivot and jewel movement.
Meter Linearity:	±2.0% full-scale.
Meter Accuracy:	±2.0% full-scale (zero center meter = 1/2 scale).
Meter Scale Gradations:	Major divisions in increments of "1". Minor divisions in increments of ".2" (2% = 1 minor division).
Meter Resistance:	660 ohms ±20%.
Battery Types:	Six each Sonotone Type S-102 and six each Sonotone Type S-104. One complete set is furnished with instrument.
Size:	Portable Model 121: 8 3/4-in. high by 6 3/4 in. wide by 10 1/2-in. deep.

Rack Model 121R: 8 3/4-in. high by 19-in. wide by 10 1/2-in. deep for relay rack mounting.

Weight: Approximately 15 pounds.

Accessories Furnished:

Mating input connector; Cannon Type RWK-3-22C-5/16-A95.

Output connector; five-way binding posts, 3/4 inch spacing (rear panel).

Solder; 12 inches of low thermal solder (Kirkson Type K275).

Input leads; untinned insulated shielded copper wire, (Leeds and Northrup Type 27-32-36).

Flux; Alpha Metals Inc.

MODIFICATIONS

Modification R: The Nanovoltmeter is mounted on an 8 3/4 in. high by 19-in. wide panel for relay rack mounting. Standard notch spacing is provided. The unit extends 10 1/2-in. behind the panel.

Modification Z: Provides wide range of zero suppression for measuring small incremental changes of larger DC voltages. Rotary-switch-selected steps with concentric vernier control are provided, covering ranges of ±0.5, ±5, ±50, ±500 and ±5000 microvolts. Operation of the zero suppression circuit is independent of the meter range selected. Stability of the zero suppression circuit is ±0.03% of the full-scale suppression range for 24 hours. The temperature coefficient is ±0.03%/°F.

3.0 OPERATING INSTRUCTIONS

3.1 EXTERNAL CONNECTIONS

3.1.1 Rear Panel Connections

The amplifier output terminals are the top two binding posts on the rear panel. The upper terminal is the high side of the output. The center terminal is the low side of the output. The center terminal is common with the low side of the input. The output is capable of driving ±5 volts at a load of 1000 ohms or greater.

In most applications, the carrying case may be used as a shield. The carrying case may be connected to the center terminal with the link provided. In some applications, it may be convenient to connect the carrying case to a different circuit such as an earth ground. The input may be floated at potentials of up to ±300 volts with respect to the carrying case and the front panel. This can occur only when the case terminal is not connected to the low side of the output.

3.1.2 Front Panel Connector

The front panel connector is the INPUT connector. The mating cable connector is a Cannon Type RWK-3-22C-5/16-A95. Pin 1 of this connector is the high side of the input. Pin 2 is the low side. Pin 3 should be connected to the shield of the input cable. Pin 3 is also connected to Pin 2 within the Nanovoltmeter.

NOTE

In the following procedural steps, control and indicator names are CAPITALIZED and UNDERLINED. Control settings are CAPITALIZED only.

3.1.3 AC Power

When the AC power cord (attached through the rear panel) is connected to a 115-V AC power source, the internal batteries automatically charge. The

Nanovoltmeter is ON only when the power ON switch is set to the ON position. The Nanovoltmeter can be operated while the batteries are being charged or when only the batteries are used for supply voltage. When the batteries are used as a power source, the AC power cord is not connected. This battery mode of operation is used whenever a completely floating Nanovoltmeter is required to minimize 60-cycle ground currents.

3.2 BATTERY OPERATION

3.2.1 Battery Charging

The instrument can be powered by its internal batteries for approximately 20 hours before recharging is necessary. It requires at least 16 hours to bring fully discharged batteries to the completely-charged state.

The batteries charge (and the CHARGE lamp lights) when the power cord is connected to the AC source. When the power ON switch is in the ON position, batteries receive one-third of the rated charging current. When the power ON switch is in the OFF position, batteries receive the full-rated charging current.

NOTE

Leaving the power cord connected will NOT damage the equipment.

3.2.2 Meter Switch

The METER switch connects the meter to the voltmeter circuit or to the internal batteries for testing. Batteries need recharging if the meter fails to reach the green area (for either polarity) when the METER switch is set to either the - BATT. or + BATT. position. The power ON switch must be set to the ON position and the power cord disconnected during this test. Battery tests do not interrupt use of the Nanovoltmeter output terminals. The INPUT position is used whenever the Nanovoltmeter is in operation.

3.3 PREPARING THE INPUT LEADS

The Model 121 Nanovoltmeter is capable of operating at extremely high gains. This instrument is also responsive to dc and very low frequency ac signals. Precautions must be taken to minimize error signals generated by the wiring between the Nanovoltmeter and the circuit under test.

3.3.1 Principles of Thermocouple Construction

Whenever two dissimilar metals are placed in contact with each other, a small emf (voltage) will be generated at the point of contact. The magnitude of this emf depends upon the character of the dissimilar metals and also upon the temperature of the junction. The operation of the thermocouple is based on the foregoing principle.

If two junctions of dissimilar metals are placed in series opposing and the junctions are operated at exactly the same temperature; the thermal emf's will cancel each other. For example; if a constantan wire is joined at each end to an iron wire, two iron-constantan thermocouples are created which are connected in series opposing. If the two junctions are maintained at the same temperature, the net emf across the ends of the iron wires will be zero.

However, if one junction is maintained at a temperature different from the second junction, an emf difference will result. For example; if one junction is at 35°C and the second junction is at 34°C, the emf appearing at the ends of the iron wires will be approximately 60 microvolts.

Table 1 lists the thermal coefficients of commonly-used junctions at 35°C. Observe that the thermal coefficient of copper and 50/50 solder is 2.87 microvolts per degree C, while the coefficient of copper and low-thermal solder is only 0.36 microvolts per degree C.

TABLE 1

Thermal Coefficients of Several Metallic Junctions (35°C)

METAL	COEFFICIENT
Iron - Constantan	60 microvolts/°C
Copper - Constantan	41 micorvolts/°C
Chromel - Alumel	40 microvolts/°C
Platinum - Platinum +13% Rhodium	7 microvolts/°C
Platinum - Platinum +10% Rhodium	6 microvolts/°C
Copper - 50/50 Solder	2.87 microvolts/°C
Copper - Brass	1.5 microvolts/°C
Copper - Low Thermal Solder	0.36 microvolt/°C

3.3.2 ASTRODATA Soldering Kit

ASTRODATA includes with each Model 121 Nanovoltmeter a low-level soldering kit (Part No. 121-1002) consisting of the following items:

1. A length of untinned copper wire.
2. A length of low-thermal solder.
3. A vial of flux.

These materials should be used in preparing the input leads for the amplifier.

CAUTION

When soldering, use a new soldering tip that is free from contamination by any other type of solder.

3.3.3 Soldering Procedure

The copper leads furnished with the amplifier should be soldered to terminals 1 and 2 of the input connector, using the low-thermal solder and the special flux. Best results will be obtained if a braided shield is slipped over the input leads. This shield should be soldered to terminal 3 of the input connector. The free ends of the input leads should be soldered to the circuit under test, using the same precautions. It is recommended that the soldering tip which has been used with the low-thermal solder be set aside for future use. This tip should not be used for ordinary soldering.

NOTE

Allow soldered junctions to cool and temperatures to equalize before attempting to use the Nanovoltmeter at sensitive ranges.

The junctions formed by the low-thermal solder and copper wires have a very low thermal coefficient. Emf's generated by these junctions will tend to cancel. It is essential that junctions be operated at the same temperature if thermal emf errors are to

be avoided. Such errors will be evidenced by offset voltages at the input to the Nanovoltmeter which create an apparent zero instability or low-frequency noise.

A poorly soldered connection can also generate noise in the circuit. To minimize thermal errors, keep the junctions as close together as possible and balanced to heat exposure. An error voltage will occur if one lead is at ambient temperature and the other lead is at a higher temperature because of proximity to a heated resistor. Leads should be made from adjacent pieces of wire from the same spool in order to avoid differing coefficients caused by different grades of copper.

Where temperature gradients are unavoidable, twist the two leads together to form a cable and wrap the cable around the components. By twisting the two leads together, temperature effects on the two connections will tend to cancel out.

3.4 GAIN SELECTION

Gain and meter sensitivity are selected by the 13-position rotary RANGE switch on the front panel (see frontispiece). This switch changes the feedback network, integrating capacitor and internal gain of the amplifier, maintaining constant loop gain and amplifier time constant.

3.5 ZERO SUPPRESSION (Modification Z)

The Nanovoltmeter can be zeroed or zero suppression of an input dc offset signal can be accomplished by using the ZERO-μV rotary selector switch and VERNIER control. Ranges of ±0.5, ±5, ±50, ±500 and ±5000 microvolts, (referred to the input) are provided.

The VERNIER control provides a ten-turn continuous adjustment for each range. The stability of this circuit is ±0.03% per day of the range selected by the ZERO-μV selector switch. The temperature coefficient of this circuit is ±0.03% of the range per degree (Fahrenheit).

3.6 OVERLOAD INDICATOR

The front-panel OVERLOAD lamp lights when a DC or AC input overloads the Nanovoltmeter. This lamp indicates possible measurement errors.

4.0 THEORY OF OPERATION

4.1 GENERAL

The Model 121 Nanovoltmeter consists of the following subassemblies (Drawing 121-8001):

A. Low Level Modulator (Drawing 121-1019)
This subassembly contains the input connector, the chopper and the input transformer.

B. Front Panel Model 121Z (Drawing 121-1010)
This subassembly contains the zero-suppression circuit, the OVERLOAD indicator lamp, the battery test and meter circuit, the power switch and the CHARGE indicator.

C. Charging Circuit, Chopper Drive Circuit and Overload Circuit (Drawing 11863)

D. Range Switch Model 121 and 121Z (Drawing 121-1017)

E. D.C. Amplifier Model 121 and 121Z (Drawing 11856)
This subassembly contains the chopper amplifier, the D.C. amplifier circuit and the plus and minus 3.25-volt dc circuits.

F. Mounting Frame Subassembly (Drawing 121-8001)
This subassembly contains a power transformer, filter capacitors, battery packs, output terminals and a "mother card" which interconnects the various subassemblies. The interconnection data for the various subassemblies is shown on Drawing 121-8001.

The Model 121 Nanovoltmeter consists of a chopper-type amplifier that uses potentiometric feedback. The input signal is modulated with an instrument chopper at approximately 690 cps and is transformer-coupled to amplifier No. 1. The output of amplifier No. 1 is demodulated by the instrument chopper. Further amplification of the demodulated signal is achieved by amplifier No. 2. The RANGE selector switch causes a portion of the output signal to be

fed back to the modulator to establish the desired gain of the amplifier.

Zero correction of the amplifier or zero suppression of input signal offsets is accomplished by a switch and an adjustable potentiometer. These components feed a dc correction signal and the feedback signal to the modulator.

The conditions that arise whenever amplifiers No. 1 or No. 2 are driven to saturation (caused by the application of overscale ac or dc inputs) are recognized and indicated by the OVERLOAD lamp.

Power for the unit is provided by a set of rechargable batteries. These batteries are charged by a built-in battery charger. The battery charger operates from a standard 115-volt ac power source. The condition of the batteries can be monitored on the front-panel meter.

4.2 SCHEMATIC ANALYSIS

4.2.1 Low Level Modulator (Drawing 121-1019)

This unit consists of the input connector, the chopper and the input transformer, all of which are mounted upon a heavy metal box. All wiring within the box is accomplished with special untinned copper wire. Soldering is done with low thermal solder, using the techniques for preparing the amplifier input leads as discussed in paragraph 3.3.

Low-level, low-frequency signals are alternately routed to pins 1 and 4 of transformer T1 via contact points 1 and 3 of the chopper. This dc input signal is modulated by the action of the chopper so that there is an equal swing between the positive and negative potentials.

The output of transformer T1 is a square wave of the same frequency as that of the chopper. The amplitude of this output signal is proportional to the amplitude of the input signal. Feedback and zero suppression signals are applied to the input of transformer T1 through the orange and brown leads. Contact points 1 and 3 are physically linked with contact points 9 and 7 of the chopper. This second set of contact points demodulates or rectifies the output of amplifier No. 1.

Demodulation and modulation are performed synchronously, so that the demodulated output (after filtering) will be an amplified replica of the input signal. By counteracting the action of the chopper coil, contact points 1 and 3 of the chopper nullify the ac characteristics of the square wave and reestablish the dc signal.

Zero suppression (.5 to 5000 microvolts) of any small changes in the incoming dc voltages is routed from the zero-suppress circuitry to the center tap (ground) of transformer T1. Contact point 5 at the upper tap of the secondary of transformer T1 carries the low level modulator signals to the dc amplifier (drawing 11856).

4.2.2 Charging Circuit, Chopper Drive Circuit and Overload Circuit (Drawing 11863)

The chopper driver consists of a free-running multivibrator and a pair of emitter followers. Inputs to the low level modulator are stabilized by the chopper drive, resulting in a favorable low drift rate (less than 50 nanovolts/hour). By controlling the inputs to the modulator, a smooth response is obtained over the range from dc to 100 cps (-3db).

4.2.2.1 Chopper Drive Circuit

Pins H and M are the inputs for the plus and minus 7.2 volts dc. Circuit-common (ground) is applied to pin P. The positive 7.2 volts dc is applied to a free-running multivibrator composed of transistors Q6 and Q8 and biasing diodes CR8, CR9, CR11 and CR12. The frequency of the multivibrator is established by the time constant of capacitors C2, C3 and resistors R10, R13. The value of R10 is factory-selected to adjust the multivibrator frequency to 690 $\pm$100 cps. This frequency response activates two sets of contacts in the modulator.

The output of the multivibrator is connected to the bases of emitter followers Q5 and Q7. Outputs from these emitter followers are wired to the opposite sides of the chopper at pins R and S.

The multivibrator signal is kept out of the battery supply lines by a filter consisting of resistor R7 and capacitors C4 and C7.

4.2.2.2 Overload Circuit

The overload circuit consists of four transistors and a biasing network. This circuitry causes the OVERLOAD light to be lit when zero voltage signals appear at pin X (Drawing 121-8001). Zero voltage signals are applied to the base of transistor Q1. The output of Q2 flows to a second amplifier stage composed of transistors Q3 and Q4. Output signals at pin N are of sufficient magnitude to light the OVERLOAD lamp on the front panel when the dc amplifier No. 1 voltage is zero volts. This indicator lamp may also be lit when tolerance limits are exceeded by the battery power supply.

4.2.2.3 Charging Circuit (Drawings 121-8001 and 11863)

The battery-charging circuit consists of a transformer, a full-wave bridge rectifier and a voltage-doubler circuit.

A potential of 105-125 volts, 50-70 cps, is applied thru fuse F1 to the primary of transformer T1. Diodes CR1 thru CR4 constitute a full-wave bridge rectifier with the resultant positive and negative dc voltages applied, through a voltage doubler (C2 thru C6), to voltage supply pins K

and J. On the battery pack, "+7.2V DC" is etched at pin K and "-7.2V DC" is etched at pin J. The CHARGE lamp is lit when ac line voltage is applied to the battery charging circuit.

4.2.3 D.C. Amplifier (Drawing 11856)

This circuit card assembly contains the circuits of amplifier No. 1, amplifier No. 2, and the plus and minus 3.25-volt dc circuits.

The overall gain of the amplifier is controlled in such a way that a constant ratio of open-loop gain (forward gain) to closed-loop gain (gain with feedback applied) is established. This constant ratio is termed, "loop gain". The closed-loop gain is established by the ratio of the feedback resistors controlled by the gain selector switch. The open-loop gain is established by adjusting the gains of amplifiers No. 1 and 2 through use of the auto gain circuit. This circuitry is also controlled by the RANGE switch.

When a low closed-loop gain is desired, the feedback signal established by the feedback resistors is large. The forward gain of the amplifier is now reduced by the auto gain circuits. When high closed-loop gains are desired, the feedback signal from the feedback resistors is small and the forward gain of the amplifiers, as established by the auto gain circuit, is high. This auto gain technique maintains a constant input impedance for the

amplifier; low noise and constant bandwidth at all gain settings.

4.2.3.1 Amplifier No. 1

Low-level modulated signals are received at input pin A. Transistors Q1 and Q2 amplify the signal. A feedback path from Q2 to Q1 establishes a local degenerative feedback. The signal is further amplified by transistor Q3, whose gain is controlled by the auto gain No. 1 circuit. The signals from Q3 are further amplified by Q4 and a degenerative path from Q4 to Q3 again establishes local inverse feedback. Transistors Q5 and Q6 provide a balanced output to the demodulator portion of the chopper and modulator assemblies. These demodulated signals (two half-wave signals) are available at pins Y and Z and are fed back to the modulator unit.

The demodulated signal is filtered by resistors R19 and R20 in conjunction with capacitor C18. The filter is used to remove the 690-cps carrier signal from the demodulated output of amplifier No. 1.

4.2.3.2 Amplifier No. 2

The filtered signal is applied to the jumper between pins N and P and then applied to the input of amplifier No. 2. This amplifier is a balanced differential amplifier. Zero correction for

amplifier No. 2 is accomplished by resistors R49 and R50. The signal is amplified by transistors Q7 through Q14 and further amplified by transistors Q15, Q16 and Q17. The forward gain of amplifier No. 2 is controlled by the auto gain No. 2 circuit, which adjusts the gain of transistor Q16. The output stage, consisting of transistors Q18 (an emitter follower) and Q19 (a current source) supplies the output at pin U.

4.2.3.3 Overload Indication

Overload indication is accomplished in the following manner:

1. The signal at the collector of Q6 (pin X, Drawing 11856) is applied to the overload circuit consisting of Q1, Q2, Q3 and Q4 (Drawing 11863).

2. Whenever the signal at the collector of Q6 is zero volts, the OVERLOAD lamp is lit.

4.2.3.4 +3.25 V DC and -3.25 V DC Power Supplies (Drawing 11856)

Regulated voltage of +3.25 volts dc is established by zener diodes CR2 through CR6. Regulated voltage of minus 3.25 volts dc is established by zener diodes CR7 through CR11. These regulated voltages are used as supply voltages for the low-level stages

of amplifier No. 1 and amplifier No. 2. These two voltages are also supplied to the zero suppression circuit.

4.2.4 Front Panel Model 121 (Drawing 121-1010)

This subassembly contains the zero suppression circuit, the OVERLOAD indicator lamp circuit, the battery test and meter circuit, the power switch and the CHARGE indicator circuit.

4.2.4.1 Zero Suppression Circuit

Zero suppression is provided by a five-position rotary switch. The ZERO μV switch permits the operator to select zero suppression from ±0.5 microvolts to ±5000 microvolts. Zero suppression is routed via pins E and F, to the low level modulator. Zero-suppress circuitry uses the plus and minus 3.25 volts dc derived from the pins and minus 7.25 volts dc power circuits (Drawing 11856).

4.2.4.2 Summing Junction

Zero-suppress signals are applied to a summing junction (Drawing 121-8001). Resistors R23 and R24 are factory-selected and are used to equalize the plus and minus swings of the amplifier output. Reference should be made to Acceptance Test Procedure 70120 when adjusting either R23 or R24.

The summing junction (pin D) is connected to pin A of the range switching unit.

4.2.4.3 Battery Test and Meter Circuit (Drawing 121-1010)

Plus 7.2V DC is routed, via pin M, thru R3 to the meter circuitry when the METER switch is set to the + BATT. position. Minus 7.2V DC is routed, via pin S, thru R2 to the meter circuitry when the METER switch is set to the - BATT. position. When the METER switch is set to the INPUT position, signals from the RANGE switch are applied to the meter via pin B.

The 100/0/100 micro-amp pivot-and-jewel meter-movement is controlled by a meter circuit composed of resistors R4 thru R7, diodes CR1, CR2 and capacitor C1. Resistors R5 and R7 are factory-selected to compensate for meter scaling.

The remaining circuitry for all lamps and switches referenced on Front Panel Model 121Z (Drawing 121-1010) has already been analyzed in the Operation section of this manual.

4.2.5 Range Switch Model 121 (Drawing 121-1017)

This subassembly contains the RANGE switch circuitry with adjacent wiring for the Auto Gain No. 1 and Auto Gain No. 2 controls.

4.2.5.1 RANGE Switch

RANGE switch SW1 is a 13-position front-panel mounted selector switch that permits selection of full-scale ranges of from 0.1 microvolt to 100.0 millivolts. Ranges are adjusted by factory-selected resistors R23 and R24 (Drawing 121-8001). Pin A of the range switching unit is connected to pin D of the zero-suppress circuitry.

4.2.5.2 Auto Gains No. 1 and No. 2

The auto gain controls are used for loop gain consistency in the chopper and D.C. amplifier sections. Auto Gain No. 1, via pin D, controls the chopper amplifier open-loop gain. Auto Gain No. 2, via pin F, controls the D.C. amplifier section. One wafer of switch SW1 employing feedback resistance is etched via switch connector pin L to the output of the amplifier (Drawing 11856).

5.0 PREVENTIVE MAINTENANCE

Maintaining this equipment is primarily a matter of periodic inspection and the replacement of malfunctioning components. The unit will normally meet its performance specifications with no need for adjustment.

5.1 BASIC TROUBLESHOOTING PROCEDURE

The following suggestions are of a general nature and are based on established practices. When followed, they enable failures to be located in the shortest possible time. Any given procedure, however, is only a guide.

5.1.1 Possible Operator Error

Difficulties are often caused by errors in the use of the equipment. Therefore, when a problem is first encountered, a thorough inspection should be made of the states of all front-panel controls and lamps. All connectors should also be checked to ascertain that the proper input/output connections have been made.

The controls and indicators of any other equipment that is operating with this unit should be checked. The operator should also question the coincidence of failure with other recent occurrences such as cleaning or servicing, disconnected accessory plugs, etc. An apparent circuit failure may be caused by such factors.

5.1.2 Problem Isolation

The Model 121 Nanovoltmeter functions as an integrated network of activities. For purposes of troubleshooting, it should be divided into its major categories, e.g. amplifier, chopper driver, modulator, etc.

To isolate the problem, gather clues from all accessible check points, such as fuse indicators, voltage test points and indicator lamps. For example, assume that a light on the front panel does not light. By association, the first step would be to check the lamp bulb and then the lamp driver.

5.1.3 Check Power Circuits

All cards in this unit are provided with some form of power. Therefore, the power circuits should be the first to be questioned. All power supplies are fused and the fuse should be checked first. If it has blown, and continues to blow, the affected circuits should then be examined.

5.1.4 Checking Circuit Cards

This equipment consists mainly of plug-in printed-circuit cards. When a suspected card is located, it is most easily checked by substituting another card of the same type in its place. This should be done before any changes are made on the card assumed to be malfunctioning. A complete list of the cards used in the Nonovoltmeter is given in the List of Illustrations.

5.1.5 Troubleshooting - DC Amplifier

Complete failure occurs when the amplifier is overdriven or "locked" in either a positive or a negative direction. This difficulty may easily be isolated to one of the two amplifiers. The most

convenient troubleshooting procedure for this situation is to observe phase relationships throughout the amplifier.

1. With the input terminals shorted together, determine the polarity of the output voltage (E_o) with respect to ground.

2. Observe the polarity with respect to ground at the feedback point.

3. If the polarity at the feedback point is similar to E_o, proceed to step 5.

4. If the polarity at the feedback point is reversed from E_o, check the feedback network for open circuits or shorts to ground.

5. Proceed in the manner described above, checking phase reversal of each succeeding stage.

6. Evidence of a gain reversal at any stage will indicate a malfunction in the stage involved.

5.2 COMPONENT AND ELEMENT MAINTENANCE

The Nanovoltmeter assembly slides out of the back of the carrying case after four screws are removed from the bottom of the case. The assembly

contains three printed circuit cards and the selector switch. One card contains the DC Amplifier components, one card contains the Chopper Drive circuits, Charging circuit and Overload Lamp circuit. The third (bottom) card contains a majority of the interconnecting wiring between cards. The front panel and the range switch are also plug-in units.

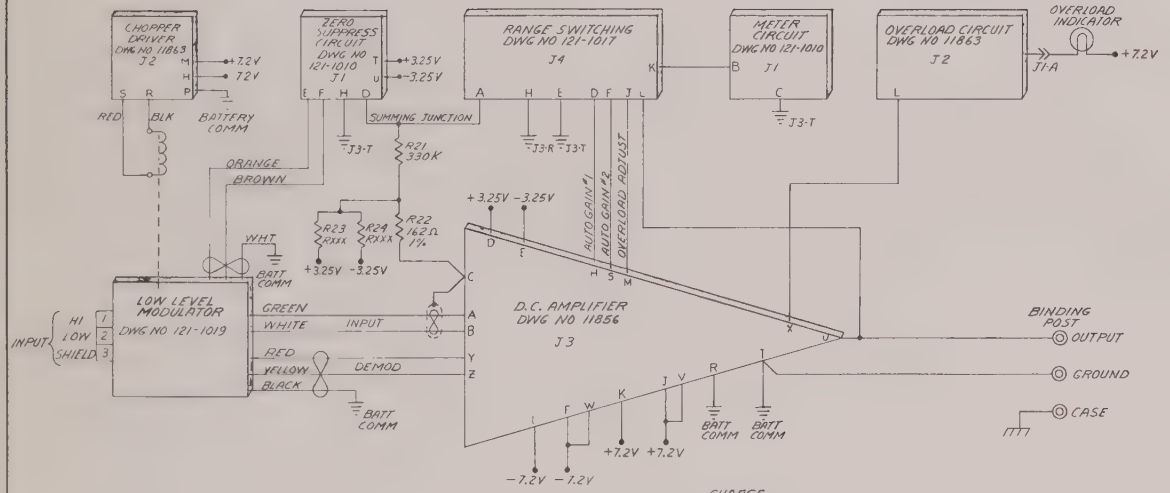
All components and elements may be replaced with stock items with the following exceptions:

1. Type 987 transistors are selected transistors. Type 2N404 transistors are aged for 400 hours and selected for low noise. The yield of transistors to this selection process has been approximately 95%. Type 987 transistors are available from ASTRODATA.

2. A James Type C2902 Chopper, with a special adjustment is used. It has been aged and selected for low noise. Other special processes have been used in the construction of the Low Level Modulator assembly. It is recommended that, in the event of failure of any part of this assembly, the entire assembly be replaced or returned to ASTRODATA for repair.

6.0 DRAWINGS

REV.	E. O.	DESCRIPTION	DWN	APPD	DATE



1		F-90X	T1	TRANSFORMER		81095
1		M535093-147	R21	RESISTOR 330K ½W, 5%	MIL-R-11	96906
1		M535093-39	R25	RESISTOR 10Ω ½W, 5%	MIL-R-11	96906
(1)		947000-1620	R22	RESISTOR 162Ω ½W, 1%	MIL-R-10509	06969
1		PMK-3-22C-5/16-P95		INPUT CABLE CONNECTOR		71468
1		312000	F1	FUSE 1/8 AMP		75915
1		VH10/1AK3	J4	CONNECTOR		05579
1		VH22/1AK3	J3			
1		VH15/1AK3	J2			
1		VH18/1AK3	J1	CONNECTOR		05579
(2)	5	89D231	C2-C6	CAPACITOR 500µf, 25V		05571
2		DF30BC		BINDING POST		58479
1		DF30GNC		BINDING POST		58479
6		S-102	B3	BATTERY		55933
3		S-109	B1, B2	BATTERY		55933
1		17206-5		A.C. LINE CORD		70903

QTY/DD	ITEM	PART NO	REF DES	DESCRIPTION	SPEC	RECOMMENDED MFR OR EQUIVALENT

LIST OF MATERIAL

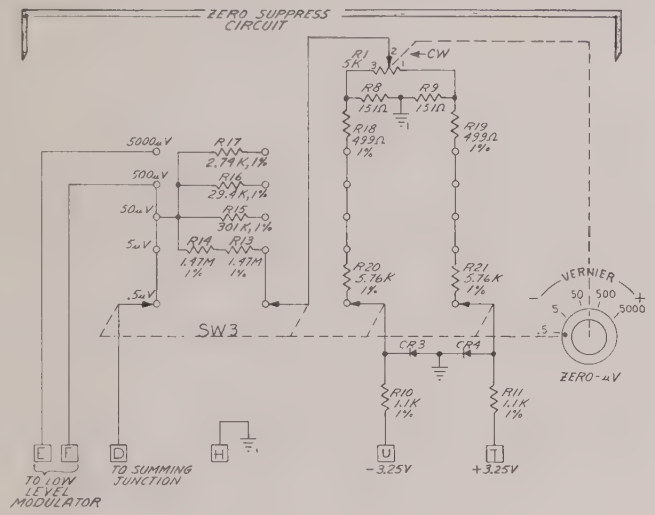
3 RYXX FACTORY SELECT.

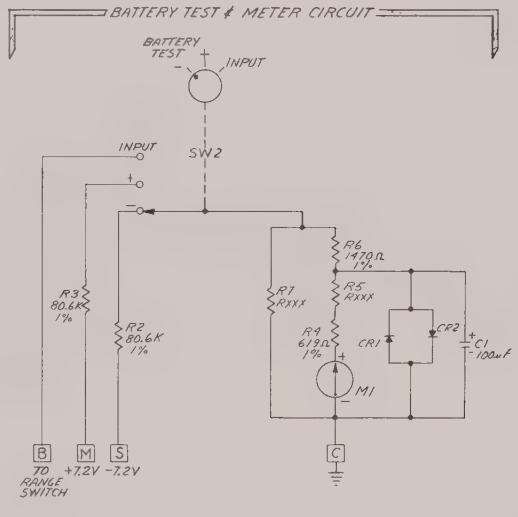
(2) SPRAGUE CAPACITOR TYPE 89D242, 500µf, 50V MAY BE USED IN PLACE OF SPRAGUE CAPACITOR 89D231, 500µf, 25V.

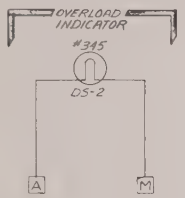
(1) RN65C, 1% SERIES RESISTORS MAY BE USED AS AN ALTERNATE FOR THE 947000 SERIES RESISTORS.

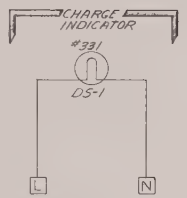
NOTE: UNLESS OTHERWISE SPECIFIED.

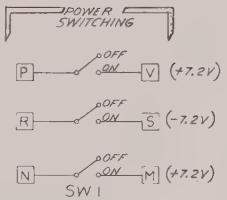
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES .XX ± .010 .XXX ± .005 ANGLES ± 1/2°	ORIGINAL DATE OF DRAWING 5/21/63	TITLE BLOCK DIAGRAM MODEL 121Z SERIAL NO. 187 UP	ASTRODATA 340 EAST PALAIS ROAD ANAHEIM, CALIFORNIA
APPLICATION NEXT ASSY USED ON	DRAFTSMAN E.C. ISLAS		
MATERIAL	CHECKER [illegible]		D 121-8001 REV
FINISH	ENGR [illegible]		
	DESIGNER	SCALE NONE IDENT CODE 06964	DWG SIZE SHEET 1 OF 1











REV	E. O.	DESCRIPTION	DWN	APPD	DATE

1		121-1008	SW3	SWITCH			06964
1		7903-B12A	SW2	SWITCH			06964
1		B2687	SW1	SWITCH			09009
(2) 2		947000-1474	R13,14	RESISTOR 1.47M ½W, 1%		MIL-R-10509	06964
1		-3013	R15	301K ½W, 1%			
2		-8062	R2,3	80.6K ½W, 1%			
1		-2942	R16	29.4K ½W, 1%			
2		-5761	R20,21	5.76K			
1		-2741	R17	2.74K			
2		-1101	R10,11	1.1K			
1		-1471	R6	1470Ω			
1		-6190	R9	619Ω			
(2) 2		947000-4990	R18,19	499Ω ½W, 1%		MIL-R-10509	06964
2		121-1015	R8,9	RESISTOR 151Ω ⅛W, 1%			06964
1		140-6308	R1	POTENTIOMETER 5K			12697
1		7903B371	M1	METER			06964
1		#345	DS2	LAMP			29455
1		#331	DS1	LAMP			29455
(1) 4		980302	CR1-4	DIODE			06964
1		VH18/1AK3		CONNECTOR			05574
1		150D107X0006A2	C1	CAPACITOR 100uf, 6V			05571
1		121-1009		P.C. BOARD			06964
QTY	ITEM	PART NO.	REF DES	DESCRIPTION		SPEC	RECOMMENDED MFR OR EQUIVALENT

LIST OF MATERIAL

3 RXXX FACTORY SELECTED.
(2) RN65C, 1% SERIES RESISTORS MAY BE USED AS AN ALTERNATE FOR THE 947000 SERIES RESISTORS.
(1) DIODE IN658 MAY BE USED AS AN ALTERNATE FOR 980302.
NOTE: UNLESS OTHERWISE SPECIFIED.

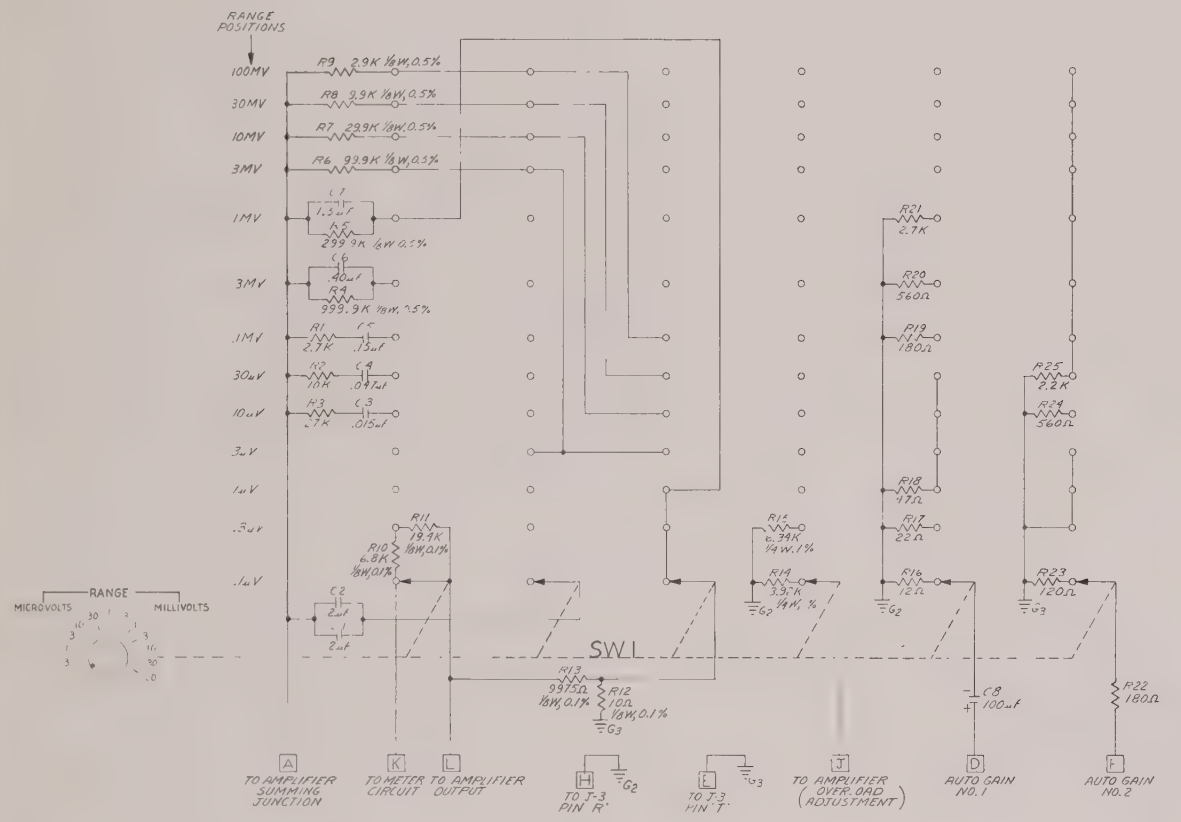
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES .XX ± .010, .XXX ± .005
APPLICATION: NEXT ASSY / USED ON / MATERIAL / FINISH

ORIGINAL DATE 5/17/63
DRAFTSMAN E.C. ISLAS
CHECKED
ENGR
DESIGNER

TITLE: FRONT PANEL MODEL 1217

ASTRODATA
240 EAST PALAIS ROAD ANAHEIM, CALIFORNIA

SCALE NONE | FSCM/T CODE 06964 | SIZE D | 121-1010 | REV | SHEET 1 OF 1



REV	E. O.	DESCRIPTION	DWN	APPD	DATE

QTY	ITEM	PART NO	REF DES	DESCRIPTION	SPEC	RECOMMENDED MFR OR EQUIVALENT
1		121-1003B	SW1	SWITCH, ROTARY		06964
1		MS35043-121	R3	RESISTOR 27K 1/2W, 5%	MIL-R-11	96906
1		-111	R2	10K		
2		-97	R1, 21	2.7K		
1		95	R25	2.2K		
2		-81	R20, 24	560Ω		
2		-69	R19, 22	180Ω		
1		-65	R23	120Ω		
1		-55	R18	47Ω		
1		-47	R17	22Ω		
1		MS35043-41	R16	12Ω 1/2W, 5%	MIL-R-11	96906
1		947000-6341	R15	6.34K 1/2W, 1%	MIL-R-10509	06964
1		947000-3921	R14	3.92K 1/2W, 1%	MIL-R-10509	06964
1		121-1015	R9	999.9K 1/8W, 0.5%		06964
1			R5	299.9K		
1			R6	99.9K		
1			R7	29.9K		
1			R8	9900Ω		
1			R9	2900Ω 1/8W, 0.5%		
1			R11	19.9K 1/8W, 0.1%		
1			R13	9975Ω		
1			R10	6800Ω		
1		121-1015	R12	RESISTOR 10Ω 1/8W, 0.1%		06964
2		PVC-12	C1, C2	CAPACITOR 2uf, 100V		37942
1		PVC-11P5	C7	1.5uf, 100V		37942
1		PVC-109	C6	.40uf, 100V		37942
1		DE2-473	C4	.047uf, 200V		99515
1		DE2-154	C3	.15uf, 200V		99515
1		DE2-153	C3	.015uf, 200V		99515
1		150D107X0006B2	C8	CAPACITOR 100uf 6V		05571
1		121-1007A		P.C. BOARD		06964

LIST OF MATERIAL

[7] RN65C, 1% SERIES RESISTORS MAY BE USED AS AN ALTERNATE FOR THE 947000 SERIES RESISTORS.
NOTE: UNLESS OTHERWISE SPECIFIED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
.XX ±.01
.XXX ±.01
ANGLES ±1/2°

MATERIAL

FINISH

APPLICATION | NEXT ASSY | USED ON

ORIGINAL DATE OF DRAWING 5/16/63
DRAFTSMAN L.C.I.S.A.S
CHECKER
ENGR
DESIGNER

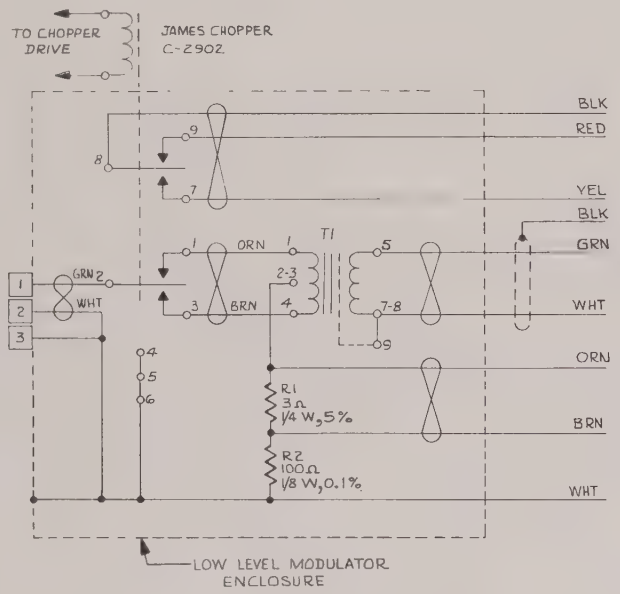
TITLE
RANGE SWITCH
MODEL 121 / 121Z

ASTRODATA
210 EAST PALA, ROAD
ANAHEIM, CALIFORNIA

D | 121-1017 | REV

SCALE NONE | IDENT CODE 06964 | DWG SIZE | SHEET 2 OF 2

REV	E O	DESCRIPTION	DWN	APPD	DATE



REQD	ITEM	PART NO.	REF DES	DESCRIPTION	SPEC	RECOMMENDED MFR OR EQUIVALENT
1		RC07GF035J	R1	RESISTOR 3Ω 1/4W, 5%		12277
1		121-1015	R2	RESISTOR 100Ω 1/8W, 0.1%		06964
1		G40479	T1	TRANSFORMER		81094
1		121-19-11-019		SOCKET, CHOPPER		71785
1		RWK-13666-2	J1	CONNECTOR		91146
1		C-2902		CHOPPER		12749

LIST OF MATERIAL

APPLICATION — NEXT ASSY — USED ON

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
XX ± .020
XXX ± .010
ANGLES ± 1/2°

MATERIAL

FINISH

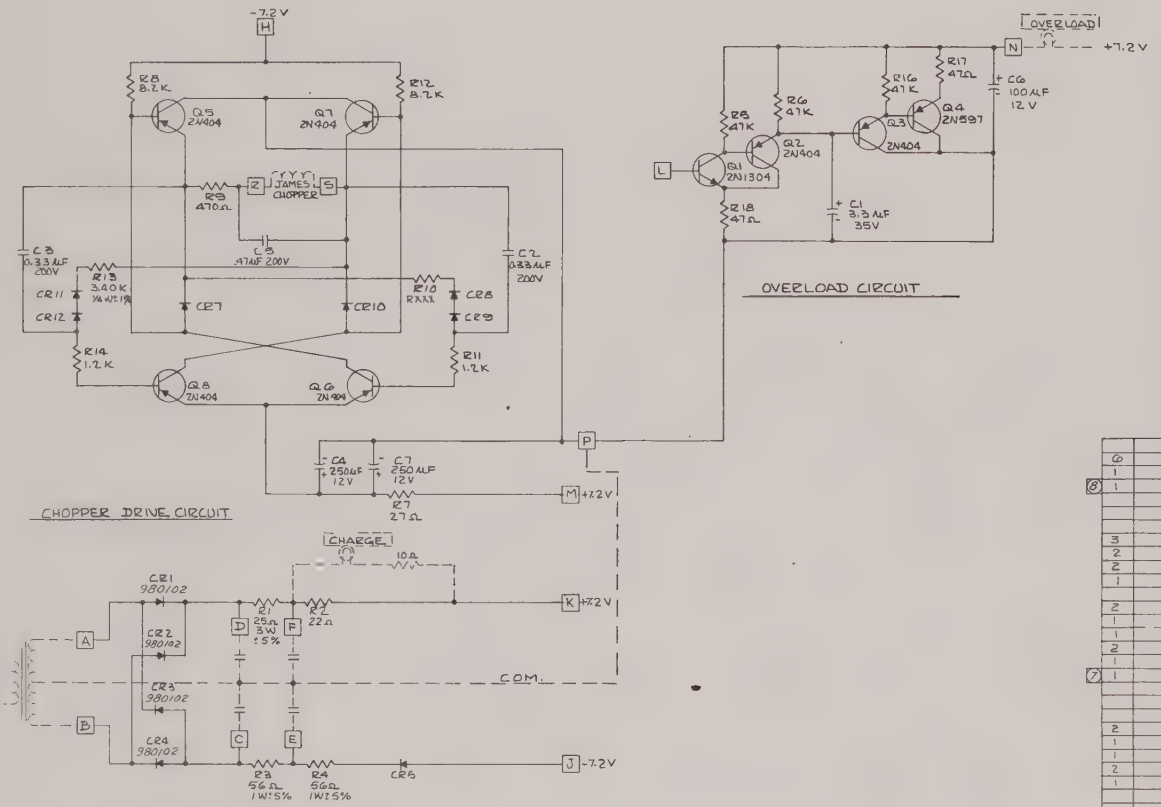
ORIGINAL DATE OF DRAWING 5-18-63
DRAFTSMAN E.C. ISLAS
CHECKER
ENGR
DESIGNER

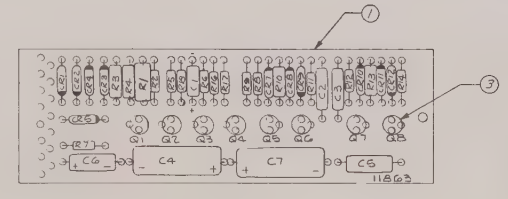
TITLE
LOW LEVEL MODULATOR

ASTRODATA
240 EAST PALAIS ROAD
ANAHEIM, CALIFORNIA

SCALE NONE | IDENT CODE 06964 | DWG SIZE C | 121-1019 | REV | SHEET 1 OF 1

REV	E. O.	DESCRIPTION	DWN	APPD	DATE
A		R10 & R13 WAS 3.83K. R10 IS RXXX, R13 IS 3.40K ¼W, 1%.	TSD	S	9-15-62
B	3256	DELETED R15 & CR6	RT	RT	11-7-62
C	3339	CR1-4 WERE IN2069, ADDED NOTES 6,7,8	EEJ	RT	6-20-63





QTY	ITEM	PART NO.	REF DES	DESCRIPTION	SPEC	RECOMMENDED MFR OR EQUIVALENT
6		2N404	Q2,3,5,6,7,8	TRANSISTOR		02735
1		2N597	Q4	TRANSISTOR		46859
(8) 1		2N1304	Q1	TRANSISTOR		93332
3		MS35043-127	R5,6,16	RESISTOR 47K ½W ±5%	MIL-R-11	96906
2		-109	R8,12	8.2K		
2		-89	R11,14	1.2K		
1		-79	R9	470Ω		
2		-55	R17,18	47Ω		
1		-49	R7	27Ω		
1		MS35043-47	R2	22Ω ½W ±5%		
2		MS35044-71	R3,4	56Ω 1W ± 5%	MIL-R-11	96906
1		AXIAL	R1	25Ω 3W 5%		44655
(7) 1		RN65B3401F	R13	RESISTOR 3.40K ¼W ±1%	MIL-R-10509	81349
2		TE-1138	C4,7	CAPACITOR 250 MF 12V		05571
1		TE-1135	C6	100 MF 12V		05571
1		ZD2N474	C5	.47 MF 200V		12406
2		ZD2N334K	C2,3	0.33 MF 200V		12406
1		150D335X0035B2	C1	CAPACITOR 3.3 MF 35V		05571
(6) 4		980102	CR1 THRU 4	DIODE		06964
(5) 7		980302	CR5, 7 THRU 12	DIODE		06964
8	3	1000-158		PAD, TRANSISTOR		06964
	2					
1	1	7303-549		PRINTED CIRCUIT BOARD		06964

LIST OF MATERIAL

(6) TRANSISTOR 2N1405 MAY BE USED AS AN ALTERNATE FOR 2N1304.
947000 SERIES RESISTORS MAY BE USED AS AN ALTERNATE FOR RN65B 1% SERIES RESISTORS.
(6) DIODE SC-2 MAY BE USED AS AN ALTERNATE FOR 980102.
(5) 1N658 MAY BE USED AS ALTERNATE FOR 980302.
4. RXXX FACTORY SELECT
3. ALL DIODES ARE 980302
2. DASH LINE CIRCUITRY IS EXTERNAL OF CARD.
1. ALL RESISTORS ¼W ±5%
NOTE: UNLESS OTHERWISE SPECIFIED

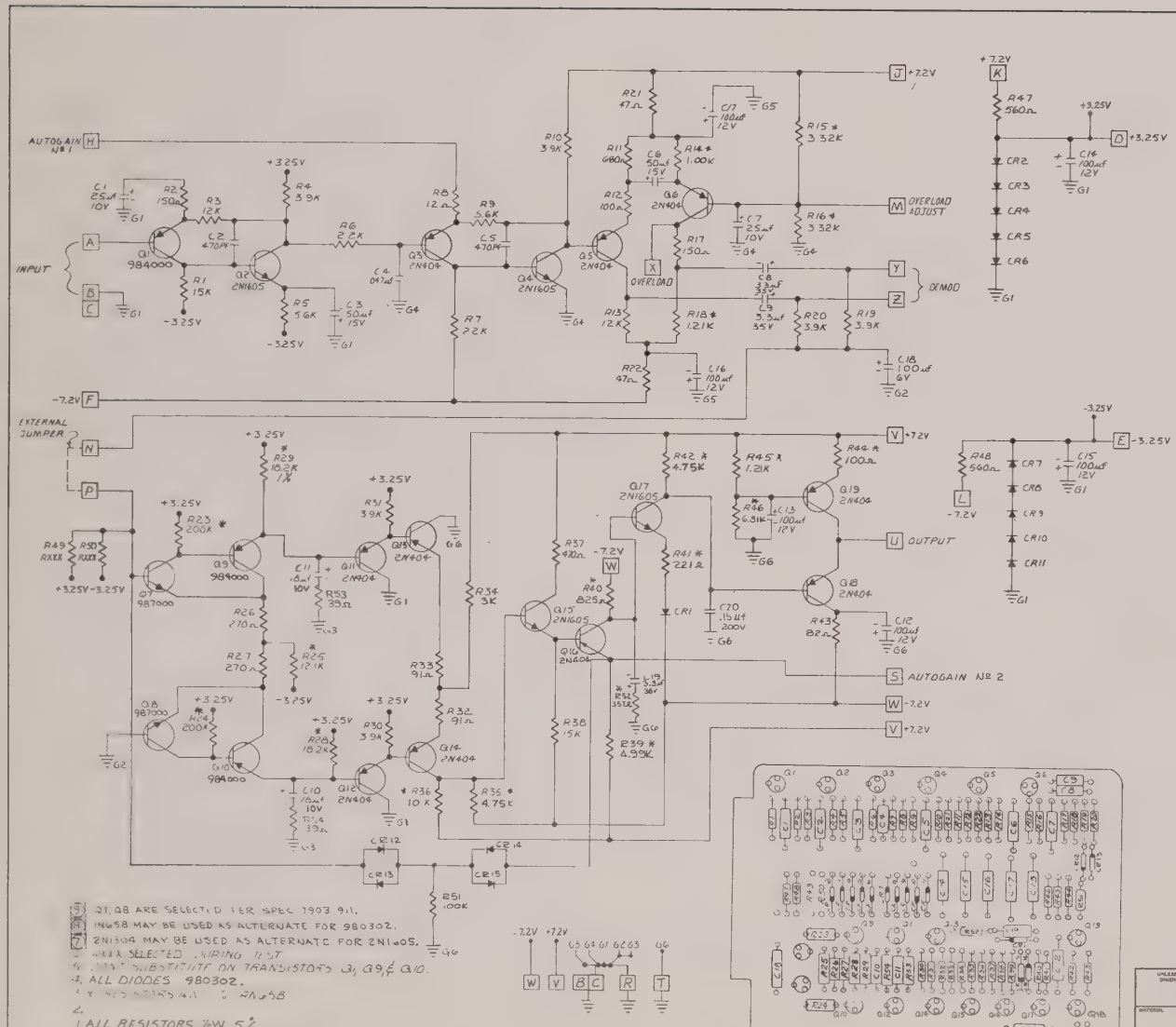
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES .XX ± .03, .XXX ± .010, ANGLES ± 1/2°

ORIGINAL DATE OF DRAWING 3-13-62
DRAFTSMAN GRANT
CHECKED DAVE PAINE
ENGR
DESIGNER Davies

TITLE
CHARGING CIRCUIT, CHOPPER DRIVE CIRCUIT & OVERLOAD CIRCUIT.
TDA 121 & 121Z
SERIAL NO 112-

ASTRODATA
240 EAST PALAIS ROAD ANAHEIM, CALIFORNIA

SCALE NONE
IDENT CODE 06964
D 11863
REV C
SHEET OF



REV	E. O.	DESCRIPTION	DWN	APPD	DATE
A	626	SEE E.O.	GCo	[illegible]	5-10-62
B	—	ADDED STD NOTES	RT	RT	1-16-63
C	2356	DELETE NOTE #2	[illegible]	RT	2-7-63

RECD	ITEM	PART NO.	REF DES	DESCRIPTION	SPEC	MFR
	2	MS 35043-53	R53, 54	RESISTOR 38Ω, ½W, 5%	MIL-R-11	
	1	RN65B2210F	R41	RESISTOR 221Ω ⅛W 1%	MIL-R-10509	
	2	MS35043-62	R32,33	RESISTOR 91Ω ½W 5%	MIL-R-11	
	1	MS35043-98	R34	3K ½W 5%	MIL-R-11	
	1	MS35043-133	R51	100K ½W 5%	MIL-R-11	
	1	RN65B4991F	R39	4.99K ⅛W 1%	MIL-R-10509	
	2	RN65B4751F	R35, 42	4.75K ⅛W 1%	MIL-R-10509	
	2	RN65B1211F	R18, 45	1.21K ⅛W 1%	MIL-R-10509	
	1	RN65B1001F	R14	1.00K ⅛W 1%	MIL-R-10509	
	1	MS35043-83	R11	680Ω ½W 5%	MIL-R-11	
	1	RN65B3570	R52	357Ω ⅛W 1%	MIL-R-10509	
	1	RN65B1000	R44	100Ω ⅛W 1%	MIL-R-10509	
	1	MS35043-41	R6	12Ω ½W 5%	MIL-R-11	
	1	-119	R7	22K		
	2	-115	R1,38	15K		
	1	MS35043-113	R3	12K ½W 5%	MIL-R-11	
	1	RN65B1002F	R36	10K ⅛W 1%		
	1	RN65B6811F	R46	6.81K ⅛W 1%	MIL-R-10509	
	2	MS35043-105	R5,9	5.6K ½W 5%	MIL-R-11	
	6	MS 35043-101	R4,10-13,20,30,37	3.9K ½W 5%	MIL-R-11	
	2	RN65B3321F	R15,16	3.32K ⅛W 1%	MIL-R-10509	
	1	MS35043-95	R6	2.2K ½W 5%	MIL-R-11	
	1	MS35043-89	R13	1.2K ½W 5%	MIL-R-11	
	1	RN65B250F	R 40	825Ω ⅛W 1%	MIL-R-10509	
	2	MS 35043-81	R 47, 48	560Ω ½W 5%	MIL-R-11	
	1	-79	R37	470Ω		
	2	-73	R26,27	270Ω		
	1	-61	R43	82Ω		
	2	-67	R2,17	150Ω		
	1	63	R12	100Ω		
	2	MS35043-55	R22,21	47Ω ½W 5%	MIL-R-11	
	2	RN65B2000F	R23,24	200K ¼W 1%	MIL-R-10509	
	2	RN65B1820F	R28,29	18.2K ¼W, 1%	MIL-R-10509	
	1	RN65B2101F	R25	RESISTOR 2.1K ¼W, 1%	MIL-R-10509	
	3	150D335X0035B2	C8, 9, 19	CAPACITOR 3.3μf 35V		SPRAGUE
	2	TE1118	C1,7	25μf, 10V		
	2	150D186X9010B2	C10,11	18μf, 10V		
	1	150D107X0006E2	C18	100μf, 6V		SPRAGUE
	1	ED2N-154	C20	.15μf, 200V		12406
	6	TE1135	C2,13,14,15,16 17	100μf 12V		SPRAGUE
	2	TE1160	C3,6	50μf 15V		SPRAGUE
	1	DE2-473	C4	.047μf		ELECTRON
	2	CM20E470J	C2,5	CAPACITOR 470 PF	MIL-C-5	
(8)	15	980302	CR1 THRU 15	DIODE		ASTRODATA
(9)	2	987000	Q7,8	TRANSISTOR		ASTRODATA
(7)	4	2N1605	Q2,4,15,17			SYL
(10)	2	2N404	Q5,6,11,12,13, 14,16,18,19			RCA
	3	984000	Q1,9,10	TRANSISTOR		ASTRODATA
	19	NOO-158		PAD, TRANSISTOR		ASTRODATA
	1	7903-520		P.C. BOARD		ASTRODATA

(5) Q1, Q8 ARE SELECTED PER SPEC 7903 9.1.
(6) 1N658 MAY BE USED AS ALTERNATE FOR 980302.
(7) 2N1804 MAY BE USED AS ALTERNATE FOR 2N1605.
(8) [illegible] SELECTED. WIRING [illegible]
(9) [illegible] SUBSTITUTE ON TRANSISTORS Q1, Q9, & Q10.
(10) ALL DIODES 980302.
[illegible] RESISTORS ¼W ± 2% 1N658
2.
1. ALL RESISTORS ⅛W 5%.
[illegible] UNLESS OTHERWISE SPECIFIED

LIST OF MATERIAL

ORIGINAL DATE OF DRAWING	2-8-62	TITLE	DC AMPLIFIER MODEL TDA-121 & 121F
DRAFTSMAN	THOMPSON		
CHECKER	DAVE PAYNE		
ENGR	[illegible]		
APPD	DAVE S		
SCALE	06364		

ASTRODATA

DWG SIZE D — 11856 — C

SHEET 1 OF 1

Warranty

ASTRODATA, Inc. guarantees this equipment to be free from defects in material and workmanship, for one year from date of delivery. Any repairs, or replacements (which alternative chosen by the manufacturer) will be carried out at the facilities of ASTRODATA, Inc. Should a defect occur in equipment which cannot be returned feasibly because of physical size, or should the defect be trivial, the purchaser will be expected to perform first echelon repairs using materials supplied by ASTRODATA, Inc. Subsequent repairs within the period of warranty will be negotiated separately.

If a defect should result from a design error, and both ASTRODATA, Inc. and the purchaser recognize this error as the cause of the defect, ASTRODATA, Inc. will correct the error to meet the specifications under which the equipment was delivered. ASTRODATA, Inc. retains the right to return the defective equipment to the company's facilities for repair should this course be deemed necessary or advisable.

Equipment, accessories, batteries, and similar items not manufactured by ASTRODATA, Inc. are subject only to adjustments as can be obtained from the original supplier by ASTRODATA, Inc.

This warranty does not apply to any equipment, or portion thereof, which becomes defective through misuse, mishandling, or environmental conditions exceeding specifications, after delivery.

No other warranties, expressed or implied, shall apply to any equipment sold under this warranty, and the foregoing shall constitute the purchaser's sole rights under the agreed terms of this warranty.

In no circumstance shall ASTRODATA, Inc. assume liability for loss, damage or consequential expense arising directly or indirectly from the use of its equipment, separately, or in combination with other equipment.